Using quantitative descriptive analysis and temporal dominance of sensations analysis as complementary methods for profiling commercial blackcurrant squashes

M. Ng , J.B. Lawlor , S. Chandra , C. Chaya , L. Hewson , J. Hort

A B S T R A C T

Quantitative descriptive analysis (QDA) is used to describe the nature and the intensity of sensory properties from a single evaluation of a product, whereas temporal dominance of sensation (TDS) is primarily used to identify dominant sensory properties over time. Previous studies with TDS have focused on model systems, but this is the first study to use a sequential approach, i.e. QDA then TDS in measuring sensory properties of a commercial product category, using the same set of trained assessors ($n = 11$). The main objectives of this study were to: (1) investigate the benefits of using a sequential approach of QDA and TDS and (2) to explore the impact of the sample composition on taste and flavour perceptions in blackcurrant squashes. The present study has proposed an alternative way of determining the choice of attributes for TDS measurement based on data obtained from previous QDA studies, where available. Both methods indicated that the flavour profile was primarily influenced by the level of dilution and complexity of sample composition combined with blackcurrant juice content. In addition, artificial sweeteners were found to modify the quality of sweetness and could also contribute to bitter notes. Using QDA and TDS in tandem was shown to be more beneficial than each just on its own enabling a more complete sensory profile of the products.

1. Introduction

Descriptive sensory techniques are used to profile a product on all its perceived sensory characteristics. Quantitative descriptive analysis (QDA) (Stone, Sidel, Oliver, Woolsey, & Singleton, 1974) is one of the most common descriptive sensory techniques used to describe the nature and the intensity of sensory properties from a single evaluation of a product. However, perception of aroma, taste and texture in foods is not a static phenomenon as the processes of eating and drinking, e.g. mastication and salivation are dynamic sensory processes. For example, the appreciation of the bitterness of beer and the taste of chewing gum depends on the timely release of taste and flavour substances. However, conventional techniques like QDA only make single point evaluations of sensory properties (Cliff & Heymann, 1993) and thus only provide an overall impression of attribute maximum intensity not the time course of a sensation. Not surprisingly, temporal methodologies have been developed to measure dynamic processes involved in flavour perception over time.

The most widely used temporal method is time-intensity analysis (Larsonpowers & Pangborn, 1978), which is an extension of conventional sensory profiling that records the evolution of a given sensory characteristic over a period of time. The result of TI measurement is typically a curve showing how the intensity of the sensation rises and falls during consumption of a product. The technique was primarily developed to study the persistence of tastes such as sweetness, bitterness and astringency (Cliff & Heymann, 1993). It has also been used for intensity evaluation on a variety of products and compounds to evaluate sourness, saltiness, irritation, flavour and aftertaste as well as to describe various textural perceptions, for a review see Piggott (2000). TI has become one of the important tools in sensory evaluation research. However, TI is time consuming as evaluation is limited to one attribute at a time and requires a large number of runs. In addition, it may also induce a halo dumping effect (Clark & Lawless, 1994) where ratings for changes in other attributes are recorded on the given scale. Analysis of time intensity data for multiple products can also be difficult. Large inter-individual differences between assessors are the main issue for most of the methodological papers (Dijksterhuis, Flipsen, & Punter, 1994; Eilers & Dijksterhuis, 2004; Ledauphin, Evelyne, & Qannari, 2006). These papers are usually focused on the description of products differences attribute by attribute, but the simultaneous analysis of time intensity data for multiple products across several attributes has also been reported by other authors (Chaya, Perez-Hugalde, Judez, Wee, & Guinard, 2004; Cordella, Leardi, & Rutledge, 2011; Ovejero-López, Bro, & Bredie, 2005).

Dual-attribute TI (DATI) was developed (Duizer, Bloom, & Findlay, 1996) to enable two attributes to be recorded simultaneously thus having the time required for single-attribute sensory evaluations. In initial dual-attribute research conducted on chewing gum (Duizer et al., 1996) was shown to offset the problems of the halo dumping effect. Although DATI is claimed to produce meaningful results (Zimoch & Findlay, 2006), DATI has not been as popular as TI due to the difficulty of the task for the panellist of recording two things at once, and therefore requires more demonstrations of its validity and value before it is widely accepted (Dijksterhuis & Piggott, 2000).

Progressive profiling (Jack, Piggott, & Paterson, 1994) was developed to ask the panellists to give an intensity score to an attribute at several time points chosen by the experimenter during the evaluation. Although progressive profiling was proposed to provide temporal information on a greater number of attributes when used to study textural attributes of hard cheese during mastication, limited correlations were found between progressive profiling, descriptive analysis and instrumental measurement (Jack et al., 1994). Having said that, similar progressive approach which was developed by Pionnier et al. (2004) showed correlations between salty perception and the level of salt in the saliva, demonstrating that there was a relationship between descriptive analysis and instrumental measurements. Despite the fact that progressive approach avoids halo dumping effect, it appeared to be as time consuming as TI methodology which could pose an issue for commercial use.

Temporal dominance of sensations (TDS) has been proposed as a different approach in the field of temporal evaluation (Pineau, Cordelle, & Schlich, 2004). It consists of presenting the panel a complete list of attributes on a computer screen and asking them to identify and sometimes rate sensations perceived as dominant until perception ends. Unlike other temporal methods, TDS enables several attributes to be evaluated simultaneously at different time points during the tasting of a product and shows the sequence of the dominant sensations. This new approach has not only reduced the duration of the experiment, it is also believed to avoid any halo-dumping effect (Pineau et al., 2004). It is claimed that the TDS methodology makes it possible to obtain temporal information for as many as 10 attributes during an evaluation but panellists have commented that it is difficult to keep in mind all the attributes simultaneously above this limit (Pineau et al., 2004). It has also been suggested not to over train panellists on using TDS method as over-trained panellist tends to quote descriptors in the same order for all products (Pineau et al., 2009) and the product evaluation may become less intuitive. It is also difficult to assess individual panellist performance in a TDS experiment due to the nature of the data. However, work measuring individual performance based on the computation of a distance index between sequences of sensations, is ongoing (Pineau et al., 2009).

Typically, TDS has been compared with TI methodology. Le Reverend, Hidrio, Fernandes, and Aubry (2008) concluded that TI and TDS brought similar information in terms of differences between products, attributes, and evolution over the time. However, the authors indicated that TDS enabled the interaction between the evolutions of attributes to be recorded in addition to the sequence of dominant sensations. TI may be better suited if the determination of the kinetic of one specific attribute is required. As it is possible to measure the intensity of dominant sensations with TDS, some scholars have attempted to relate data obtained from TDS with conventional QDA profiling. For example, Labbe, Schlich, Pineau, Gilbert, and Martin (2009a) compared description of gels containing different levels of odorants, citric acid, cooling agent and xanthan gum obtained with TDS and QDA methodologies. They concluded that TDS provided information on the dynamic of perception after product consumption that was not available using conventional sensory profiling which may be important in understanding complex perceptions such as refreshing. In addition, Meillon, Urbano, and Schlich (2009) showed that TDS differentiated between partially dealcholised red wines on twice as many attributes as conventional sensory methods. Further more, TDS illustrated temporal differences between wines that did not appear with the conventional sensory profile. Both these studies underlined a drawback of conventional sensory profiling methods in estimating the qualitative changes of dominance of the sensations during and after food consumption.

Furthermore, Labbe et al. (2009a) used separate panels for their comparative research, and, although Meillon et al. (2009) used the same panel, their investigation was performed on a model system. In this study we compare both techniques using commercially available products using the same panellists and additional replication. We aim to add to the robustness of the data and the general discussion comparing the relative merits of TDS and QDA, in particular, its commercial relevance within a product category.

The main objectives of this study were to: (1) discuss the benefits of using a sequential approach of QDA and TDS in measuring commercial blackcurrant squashes and (2) to explore the impact of the sample composition on taste and flavour perceptions in blackcurrant squashes.

2. Materials and methods

2.1. Subjects

Eleven trained panellists (aged 30–55 years, one male) from GlaxoSmithKline's (GSK) were invited to participate in the study. All panellists had been members of the GSK sensory panel for between 5 and 15 years and had extensive experience evaluating blackcurrant drinks.

2.2. Samples

Eleven commercial blackcurrant squashes were selected which represented the variation in sensory characteristics of the UK product space (see Table 1 for product composition). All products were prepared using filtered tap water according to their corresponding dilution factors and were served at 16 ± 2 °C.

2.3. Quantitative descriptive analysis (QDA)

The samples were profiled using quantitative descriptive analysis (QDA) (Stone et al., 1974). The panel had already been trained to assess blackcurrant squashes using the QDA technique for previous projects. However, to ensure reliability and accuracy of the data, the panel attended a further six two-hour training sessions to generate aroma (A), taste (T), flavour (F) and aftertaste (AT) attributes and to verify the use of attribute scales for the product range to be tested in this project. The attribute generation stage identified 24 attributes which were reduced through discussion to a list of 15 which discriminated across the products (Table 2).

The 11 blackcurrant squashes were evaluated in triplicate over three two-hour sessions according to a balanced design. All attributes were rated on unstructured line scales, anchored at the extremities with 'not at all intense' and 'very intense'.

Products (50 ml) were presented monadically, in sets of three, with breaks of 15 min between sets and a minimum of 1 min between the products to ensure no carry-over effects. Unsalted crackers and filtered tap water were used as palate cleansers. All tests were conducted at room temperature in an air-conditioned room, under Northern Hemisphere daylight and in individual booths.

Table 1
Product composition after dilutions.

Product code	Dilution ratio	After dilution (per 50 ml serving)			Sweeteners	Other ingredients
		BC juice[a] (%)	Sugar (g/ 50 ml)	pH[b]		
1	1:5	2	3.7	2.8	Glucose fructose syrup	Citric acid, preservatives, flavouring, antioxidant
2	1:5	1.4	0.2	3.7	Aspartame, Acesulfame K	Citric acid, malic acid, preservatives, flavouring, antioxidant, acidity regulator, colouring, stabiliser
3	1:6	2.04	2.6	2.9	Glucose	–
4	1:7	0.41	2.3	3.1	Organic glucose	0.2% organic lemon and apple juice (after dilution per 50 ml), citric acid
5	1:5	2	2.3	3.0	Glucose	Citric acid, preservatives, flavouring
6	1:5	2	0.2	3.3	Sucralose	Citric acid, preservatives, flavouring, acidity regulator, colouring
7	1:5	0.88	2.9	2.8	Glucose	Citric acid, preservatives, flavouring, antioxidant, colouring
8	1:5	1.4	0.2	3.4	Sucralose, Acesulfame K*	Citric acid, preservatives, flavouring, antioxidant, acidity regulator, colouring, stabiliser
9	1:5	1.6	2.7	2.8	Glucose	Citric acid, preservatives, flavouring, antioxidant
10	1:11	0.43	0.4	3.7	Aspartame, Sodium Saccharin	Citric acid, preservatives, flavouring, antioxidant, acidity regulator, colouring
11	1:5	1	2.7	2.8	Glucose	Citric acid, preservatives, antioxidant, colouring

[a] Blackcurrant juice content taken from nutritional labelling.
[b] Measured when diluted according to label instructions using a pH 211, Microprocessor pH metre, HANNA Instruments.

Table 2
List of sensory attributes with agreed definition.

Sensory attributes	Modality[a] A/F/T/AT	Definition
Veggie	A	Tinned vegetable water as found inTesco tinned mixed vegetables (in salt water)
Watery	F	Weak and watery flavour of an over-diluted squashes
Natural processed blackcurrant	A/F/AT	Fruity blackcurrant as found in processed blackcurrants: ribena original blackcurrant concentrate (diluted to drink)
Confectionary blackcurrant	A/F/AT	Complex confectionery blackcurrant flavourings as found in wine gums, pastilles, jelly babies and boiled sweets
Fresh blackcurrant	A/F/AT	Pureed fresh blackcurrants
Tomato ketchup	A/F/AT	Complex tomato, vinegar and spices as found in tomato ketchup
Catty	A/F/AT	Crushed leaves from a flowering currant bush
Green and leafy	A/F/AT	Crushed blackcurrant leaves
Earthy	A/F/AT	Damp dirt and vegetation
Minty	A/F/AT	Indefinable peppermint as found in mouthwash
Natural sweetness	T/AT	Basic taste of sweetness as found in sucrose solution
Artificial sweetness	T/AT	Taste of artificial sweeteners® aspartame
Acidic	T/AT	Basic taste of acidity as found in citric acid solution
Bitter	T/AT	Basic taste of bitterness as found in caffeine solution
Astringent	AT	Drying sensation in the mouth after swallowing

[a] Modality: A (Aroma), F (Flavour), T (Taste), AT (Aftertaste).

QDA data were collected using FIZZ software (Biosystem, Couternon, France).

2.4. Temporal dominance of sensations (TDS)

The panel had no previous experience using TDS and therefore attended six two-hour training sessions. Panellists were introduced to the notion of temporality of sensations using the analogy of an orchestra playing music. A dominant sensation was defined as a sensation that triggers the most attention at a point of time (Pineau et al., 2009). The panellists were then trained to use the computerised TDS data capture system (FIZZ, Biosystemes, Couternon, France) and to evaluate the products following the protocol described below (Pineau et al., 2009).

Pineau et al. (2009) indicated that a maximum of 10 attributes could be evaluated using TDS. In this project 12 attributes were selected based on the PCA of the QDA data. However, three attributes related to blackcurrant ('natural processed', 'confectionary' and 'fresh') and two related to sweetness ('natural' and 'artificial'). QDA indicated that any one product only exhibited one type of blackcurrant or sweetness attribute and hence the list of attributes for TDS was reduced to nine: 'blackcurrant', 'sweet', 'tomato ketchup', 'catty', 'minty', 'earthy', 'acidic', 'bitter' and 'astringent'. The TDS data for the blackcurrant and sweetness attributes could then be further interpreted by looking at the QDA to determine the nature of the blackcurrant and sweetness.

The nine attributes were presented simultaneously on the computer screen with their corresponding unstructured line scale anchored at the extremities with 'not at all intense' and 'very intense' as for QDA. Panellists were instructed to put the product in mouth and click on the start button to begin the evaluation. At 15 s, panellists were cued on screen to swallow the product and continue their evaluation until no sensation was perceived, at which point they were instructed to click the stop button unless data acquisition had automatically stopped after the agreed 60s. Panellists were asked to identify and rate the intensity of sensation they perceived as dominant while performing the tasting protocol. They were informed that they did not have to use all the attributes in the list and were allowed to choose the same attribute several times throughout the evaluation or conversely to never select an attribute as dominant. Attribute order presentation was different for each panellist to avoid order effects, but attribute order was maintained within each panellist to facilitate scoring.

The 11 blackcurrant squashes were evaluated in triplicate over three two-hour sessions according to a balanced design. Products (50 ml) were presented monadically, in sets of two with breaks of 15 min between sets and a minimum of 1 min was allowed between the products to ensure no carry-over effects. TDS data were collected using FIZZ software (Biosystem, Couternon, France).

2.5. Data analysis

2.5.1. QDA

Two-way (product and panellists) fixed model analysis of variance (ANOVA), with interaction, was carried out to determine which attributes discriminated between products and subsequently, if this was related to product composition. Where appropriate, Tukey's HSD multiple comparison tests were used to determine which products differed from each other ($\alpha = 0.05$) (FIZZ, Biosystemes, Couternon, France). Pearson principal component analysis (PCA) was performed on the QDA mean panel data (XLSTAT Version 2009.6.03, Addinsoft, USA) to provide further multivariate graphical representation of the product space.

2.5.2. TDS

For each attribute, a TDS score and dominance rate at each time point was calculated. The TDS score is the mean intensity of an attribute (weighted by duration), as defined according to Eq. (1):

$$\text{Score}: \left(\sum \text{Intensity} \times \text{Duration}\right) / \left(\sum \text{Duration}\right) \quad (1)$$

The dominance rate is the percentage of selections of an attribute as dominant at a particular time point. The higher the dominance rate, the better the agreement among panellists. TDS curves, whereby dominance rates are plotted against standardised time, were created for each attribute (Pineau et al., 2009). Each panellist's time data was standardised to a score between 0 and 100, 0 representing when they clicked start and 100 when they clicked stop or after 60 s when recording stopped automatically. Spline based smoothing was applied on each curve.

Two-way (product and panellists) fixed model analysis of variance (ANOVA), with interaction, was computed on TDS scores to determine which attributes discriminated between products and if this was related to product composition. Attributes not selected during TDS were considered to have an intensity and duration of zero. Tukey's HSD multiple comparison tests were performed to know which products significantly differed from one another ($\alpha = 0.05$). Pearson principal component analysis (PCA) was carried out on TDS score mean panel data to identify the key attributes contributing the most to the variation in products within the product space (XLSTAT Version 2009.6.03, Addinsoft, USA).

2.5.3. Comparison of TDS to QDA data

The relationship between the mean panel data on the 11 products for both QDA and TDS scores was analysed by the RV coefficient with SPADN (Système Portable d'Analyse des Données Numériques) software. The RV coefficient provides a measure of correlation between the two data sets allowing the similarity of the product configurations in the sensory profiling space and in the TDS space to be evaluated.

3. Results

3.1. Product differences ascertained by QDA

Tables 3a–e list the mean attribute scores for aroma (A), flavour (F), taste (T) and aftertaste (AT) for each of the 11 products, respectively. ANOVA revealed that for all 15 attributes, significant ($p < 0.001$) product differences were observed. The product groupings indicated by the Tukey's HSD multiple comparison test are also shown in Tables 3a–e. The first three principal components of the QDA PCA accounted for 84% of the variance in the data. Fig. 1 illustrates the correlation circle for PC1 versus PC2 and PC1 versus PC3. PC1 (35%) was positively correlated with 'fresh blackcurrant' (A, F, AT), 'green and leafy' (A, F, AT), 'earthy' (A, F, AT), 'natural sweetness' (T, AT), 'acidic' (T, AT) and negatively correlated with 'confectionary blackcurrant' (A, F, AT) and 'artificial sweetness' (T, AT). PC2 (28.3%) was positively correlated with 'bitter' (T, AT), 'minty' (F, AT), 'catty' (A, F, AT) and negatively correlated with 'tomato ketchup' (A, F, AT). PC3 (20.7%) was positively correlated with 'natural processed blackcurrant' (A, F, AT) and negatively correlated with 'watery' (F).

Products 3, 4 and 10 are clearly distinct from each other as well as being notably different from the remaining products. PC1 from the QDA PCA (Fig. 2a) clearly differentiated between products 10 and 3, especially in terms of the nature of the blackcurrant flavour. Product 10 was characterised by 'confectionary blackcurrant' (A, F, AT) whereas the flavour of product 3 was described as 'fresh blackcurrant' (A, F, AT) and was also accompanied by other complex flavours such as 'green and leafy' (A, F, AT), and 'earthy' (A, F, AT) which were all significantly lacking in product 10. PC1 was also strongly related to the attribute sweetness; added sugar squashes, i.e. products 1, 3, 4, 5, 7, 9 and 11 were associated with high positive values for 'natural sweetness' (T, AT) whereas artificially sweetened squashes, i.e. products 2, 6, 8 and 10 were associated with 'artificial sweetness' (T, AT). PC2 clearly differentiated between products 4 and 10 on several characteristics. Product 4 was significantly different from other products in terms of its 'tomato ketchup' (A, F, AT) whereas product 10 was characterised as 'bitter' (T, AT) and 'catty' (A, F, AT). The positioning of the 'watery' attribute in Fig. 2b indicated that PC3 was associated with the level of dilution, together with 'natural processed blackcurrant' flavour. Eight products placed in the middle of the bi-plot (i.e. products 1, 2, 5, 6, 7, 8, 9 and 11) were all characterised by a similar intensity of 'natural processed blackcurrant' (A, F, AT).

3.2. Use of QDA to select TDS attribute list

As mentioned earlier, the attribute list for TDS was built based on QDA data. The TDS data for the blackcurrant and sweetness attribute were then further interpreted by looking at the QDA to determine the nature of the blackcurrant and sweetness for respective products, e.g. the flavour of product 3 was characterised by 'fresh blackcurrant' and 'natural sweetness' and product 6 was characterised by 'natural processed blackcurrant' and 'artificial sweetness'.

Table 4 lists the mean TDS score for all attributes for each of the 11 products, respectively. ANOVA revealed that for all attributes, significant ($p < 0.001$) product differences were observed. The product groupings indicated by the Tukey's HSD multiple comparison test are also shown in Table 4. The first three principal components of the TDS PCA accounted for 84.3% of the variance in the TDS scores. Fig. 3 illustrates the correlation circle for PC1 versus PC2 and PC1 versus PC3. PC1 (33.6%) was positively correlated with 'fresh blackcurrant', 'earthy', 'astringent', 'acidic' and 'bitter'. PC2 (29.5%) was positively correlated with 'artificial sweetness', 'catty' and 'confectionary blackcurrant' and negatively correlated with 'natural sweetness'. PC3 (21.2%) was positively correlated with 'natural processed blackcurrant' and 'minty' and negatively correlated with 'tomato ketchup'. The bi-plot of PC1 versus PC2 (Fig. 4) separated groups of products into each quadrant, with products 3 and 10 clearly distinct from the others. The bi-plot of PC3 with PC1 further separated product 4 from the large group of remaining products.

3.3. Comparison of QDA and TDS SCORE results

A visual inspection of both bi-plots for TDS and QDA (Figs. 2 and 4) indicated that product positioning is similar for both methods.

Table 3a
QDA mean panel data (*stdev*) and post hoc test groupings for aroma intensity of 11 blackcurrant samples.

Product	Aroma																	
	Veggie		Natural processed blackcurrant		Confectionary blackcurrant		Fresh blackcurrant		Tomato ketchup		Catty		Green and leafy		Earthy		Minty	
1	1.9	6.1^{B}	39.5	12.8^{A}	7.8	12.6^{B}	0	0.2^{B}	0	0^{B}	0.6	3.1^{B}	13.2	12.2^{ABCD}	11.6	12.9^{AB}	4.3	9.5^{AB}
2	16.8	16.6^{A}	35.5	17.0^{A}	11.1	17.7^{B}	0	0^{B}	0	0.2^{B}	0	0^{B}	9.6	12.9^{BCD}	9.9	12.9^{AB}	12.8	18.5^{A}
3	0.5	2.3^{B}	8.5	11.7^{B}	0	0^{B}	46.8	11^{A}	0	0^{B}	4	$13.\ 6^{B}$	25.2	9.8^{A}	20.9	13.6^{A}	0	0.2^{B}
4	9.5	10.8^{AB}	5.9	10.6^{B}	1.5	4.6^{B}	0.1	0.2^{B}	44	8.5^{A}	0	0^{B}	0	0^{D}	0.9	2.9^{B}	0	0^{B}
5	5.8	12.6^{AB}	35.9	16.9^{A}	2.6	7.2^{B}	3.2	8.1^{B}	0	0^{B}	2.8	7.8^{B}	18.2	15.9^{ABC}	6.5	9.5^{B}	0.8	3.2^{B}
6	4.8	11.3^{AB}	35.6	17.1^{A}	10.1	13.9^{B}	2.3	10^{B}	0	0.2^{B}	5.4	11.9^{B}	16.3	17.3^{ABC}	9.3	11.2^{B}	2.7	6.6^{AB}
7	9.0	15.9^{AB}	36.6	7.6^{A}	2.5	6.1^{B}	0	0.2^{B}	0	0.2^{B}	0.7	4.2^{B}	14.5	12.7^{ABC}	3.8	7.9^{B}	2	6.3^{B}
8	6.4	12.4^{AB}	38.8	10.2^{A}	5.7	8.5^{B}	0	0.2^{B}	0	0^{B}	2.1	6.8^{B}	15	15.3^{ABC}	2.9	6.6^{B}	0	0.2^{B}
9	3.5	8.2^{B}	40.0	10.5^{A}	6.6	10.7^{B}	0	0^{B}	0	0^{B}	1.9	5.5^{B}	20.4	12.6^{AB}	5.6	9.4^{B}	3.1	6.8^{AB}
10	0	0.2^{B}	9.0	15.7^{B}	42.5	18.3^{A}	0	0^{B}	0	0^{B}	18.9	17.4^{A}	4.9	11.2^{CD}	4	9.9^{B}	8.3	11^{AB}
11	2.4	5.8^{B}	36.5	10.4^{A}	2.9	9.59^{B}	0	0^{B}	0	0.2^{B}	1.6	6.3^{B}	17.3	13.2^{ABC}	4.1	7.6^{B}	1.9	5.4^{B}

Samples with the same letter (ABCD), within a column, are not significantly different from each other ($p < 0.05$).

Table 3b
QDA mean panel data (*stdev*) and post hoc test groupings for flavour intensity of 11 blackcurrant samples.

Product	Flavour																	
	Watery		Natural processed blackcurrant		Confectionary blackcurrant		Fresh blackcurrant		Tomato ketchup		Catty		Green and leafy		Earthy		Minty	
1	1.2	4.6^{C}	45.5	11.9^{A}	13.7	17.1^{B}	0	0^{B}	0	0.2^{B}	0	0.2^{B}	14.4	14.5^{ABCDE}	7.8	11.2^{B}	8.9	11.1^{ABC}
2	4.6	13.6^{BC}	39.2	15.2^{A}	10.4	16.1^{BC}	0	0^{B}	0	0^{B}	0	0.2^{B}	5.5	10.4^{CDE}	8.5	12^{B}	13.8	13.8^{A}
3	17.3	16.4^{AB}	8.3	11.9^{B}	0	0.2^{C}	45.8	9.5^{A}	0	0^{B}	2.2	7^{B}	24	10.2^{A}	19.3	13.2^{A}	2.3	5.2^{BC}
4	27.5	13.6^{A}	6.5	11.6^{B}	1.5	4.8^{BC}	0	0^{B}	40.2	11.6^{A}	0	0^{B}	2.5	8^{E}	0.7	2.4^{B}	0	0^{C}
5	3	8.4^{C}	38.4	18^{A}	2.6	7.5^{BC}	6.2	14^{B}	0	0.2^{B}	2	6.3^{B}	17.2	14.1^{ABC}	5.8	9.5^{B}	3.8	7.2^{BC}
6	10.6	16.7^{BC}	37.8	15.7^{A}	11.1	13.2^{BC}	0.8	4.4^{B}	0	0^{B}	5.1	11.3^{B}	10.2	11.5^{BCDE}	7.2	9.9^{B}	10.7	11.5^{AB}
7	8.9	15.7^{BC}	42.7	8.8^{A}	5.1	9.3^{BC}	0	0^{B}	0	0.2^{B}	0.1	0.2^{B}	11.6	11^{BCDE}	4.2	8.7^{B}	5.5	8.7^{ABC}
8	7.9	14.6^{BC}	43.1	12.7^{A}	6.3	8.8^{BC}	0	0.2^{B}	0	0^{B}	0.3	1.9^{B}	13.2	13.3^{ABCDE}	3.2	7.7^{B}	7.6	12.4^{ABC}
9	6.1	13.1^{BC}	43.2	12.9^{A}	6	9.9^{BC}	0	0^{B}	0	0^{B}	1.7	4.6^{B}	20.3	12.6^{AB}	6.5	9.7^{B}	9.2	9.7^{ABC}
10	11.7	16.9^{BC}	8.6	15.2^{B}	43.6	15.2^{A}	0	0.2^{B}	0	0^{B}	19.4	17.8^{A}	4.8	9.9^{DE}	3.6	9.2^{B}	9.9	11.1^{AB}
11	10.6	16.4^{BC}	40.2	12.1^{A}	2.1	7.4^{BC}	0	0.2^{B}	0	0.2^{B}	0.5	2.4^{B}	16.6	12^{ABCD}	6.5	9.2^{B}	6.1	8.1^{ABC}

Samples with the same letter (ABCD), within a column, are not significantly different from each other ($p < 0.05$).

Table 3c
QDA Mean panel data (*stdev*) and post hoc test groupings for taste intensity of 11 blackcurrant samples.

Product	Taste							
	Natural sweet		Artificial sweet		Acidic		Bitter	
1	40.2	27.4^{AB}	0	0^{C}	45.7	10.7^{AB}	32.2	14.1^{BC}
2	3.1	12.4^{D}	29.4	27.1^{AB}	46.3	9.3^{AB}	42.6	14^{A}
3	35.9	17^{AB}	0.1	0.2^{C}	50.6	16.9^{A}	42.4	19^{A}
4	29	24.1^{ABC}	0	0.2^{C}	39.6	10.3^{BC}	30.2	12.5^{C}
5	37.9	20.5^{AB}	0.1	0.4^{C}	50.9	14.2^{A}	37.1	15.3^{ABC}
6	18.8	20.4^{BCD}	10.2	18.8^{BC}	47.5	13.2^{A}	37.5	15.6^{ABC}
7	41.1	23.5^{A}	1.7	9.4^{C}	43.9	11.7^{ABC}	31	14.1^{C}
8	13.2	20.6^{CD}	26.6	28.4^{AB}	46.9	10.1^{AB}	40.6	15.3^{AB}
9	39.6	23.2^{AB}	1.3	7.1^{C}	49.6	12.7^{A}	37.3	15.3^{ABC}
10	1.6	8.9^{D}	42.7	24.8^{A}	43.6	11^{ABC}	39	11.6^{ABC}
11	40	21.6^{AB}	0	0^{C}	44.3	14^{ABC}	31.4	17.4^{BC}

Samples with the same letter (ABCD), within a column, are not significantly different from each other ($p < 0.05$).

Products 3, 4 and 10 are separated from the rest of the products on each PCA in terms of the differing nature of the blackcurrant flavour: product 3 is described as 'fresh' whereas product 10 is 'confectionary' blackcurrant; and/or additional flavours: 'earthy' (product 3), 'tomato ketchup' (product 4) and 'catty' (product 10). Products 2, 8 and 6 are also positioned together on both plots. The remaining products, i.e. products 1, 5, 7, 9 and 11, tend to congregate together in the middle part of both plots. This similarity is confirmed by a high RV coefficient of 0.819 between the two data matrices.

3.4. Additional temporal information obtained by TDS

Unlike QDA, TDS provided dominance curves which are used to illustrate the temporal changes of dominant attributes during and after the drinking process. Fig. 5 illustrates the standardised TDS dominance curves for each product. Each curve represents the evolution of the dominance rate of an attribute over standardised time (%). In order to facilitate the interpretation of TDS curves, two other additional lines (chance and significance) are displayed on each TDS graph. The chance limit represents the dominance rate that

Table 3d
QDA mean panel data (*stdev*) and post hoc test groupings for aftertaste (flavour) intensity of 11 blackcurrant samples.

Product	Aftertaste (Flavour)															
	Natural processed blackcurrant		Confectionary blackcurrant		Fresh blackcurrant		Tomato Ketchup		Catty		Green and Leafy		Earthy		Minty	
1	29.1	6.7^{A}	9.4	12.5^{B}	0	0^{B}	0	0^{B}	0	0^{B}	9.3	11^{ABCD}	6.6	9.7^{B}	7.3	9.6^{AB}
2	26	9.8^{A}	7.9	12.3^{B}	0	0^{B}	0	0^{B}	0.1	0.3^{B}	4.6	9.2^{BCD}	6.1	9.6^{B}	11.5	12.3^{A}
3	7.3	9.9^{B}	0	0.2^{B}	29.4	8.7^{A}	0	0^{B}	1.1	4.5^{B}	18.6	7.2^{A}	16.5	11.1^{A}	2.2	5^{B}
4	4.1	9.3^{B}	1.4	4.3^{B}	0.1	0.4^{B}	28.6	8.5^{A}	0	0^{B}	2.6	8.4^{D}	0.8	2.9^{B}	0	0.2^{B}
5	26.7	11.3^{A}	2.4	6.6^{B}	1.6	5.4^{B}	0.1	0.2^{B}	0.6	2.6^{B}	13.2	11.5^{ABC}	4.8	7.9^{B}	3.3	6.1^{AB}
6	24.3	10^{A}	9.4	10.9^{B}	0.4	2.4^{B}	0.1	0.2^{B}	2.9	7.1^{B}	9.6	10.1^{BCD}	5.9	7.6^{B}	9.1	10.3^{AB}
7	27.3	7.4^{A}	3.6	7.3^{B}	0	0^{B}	0	0.2^{B}	0	0.2^{B}	9.4	8.8^{ABCD}	3.8	7.6^{B}	5.4	8.5^{AB}
8	26.7	7.8^{A}	7.2	9.9^{B}	0	0^{B}	0	0.2^{B}	0	0^{B}	10.7	11.4^{ABCD}	1.1	3.7^{B}	6.2	9.4^{B}
9	28.3	8.7^{A}	6.3	9.8^{B}	0	0.2^{B}	0	0.2^{B}	0.8	3.2^{B}	13.9	12.2^{AB}	4.8	8.7^{B}	7.3	8.6^{AB}
10	7.1	12.1^{B}	29.5	9.8^{A}	0.1	0.2^{B}	0.1	0.2^{B}	15.3	13.4^{A}	4.5	9.5^{BCD}	2.7	6.3^{B}	8.4	9.1^{B}
11	26.9	7.6^{A}	1.8	5.7^{B}	0	0^{B}	0	0^{B}	0.1	0.3^{B}	13.8	11^{AB}	3.9	7.5^{B}	4.2	7.3^{AB}

Samples with the same letter (ABCD), within a column, are not significantly different from each other ($p < 0.05$).

Table 3e
QDA mean panel data (*stdev*) and post hoc test groupings for aftertaste (taste) intensity of 11 blackcurrant samples.

Product	Aftertaste (Taste)									
	Natural sweet		Artificial sweet		Acidic		Bitter		Astringent	
1	30.6	22.8^{AB}	0	0^{C}	41.7	13.2^{ABC}	29.2	12.1^{BCD}	50.5	10.6^{BCD}
2	2	8^{C}	26.1	25.5^{A}	42.2	13.6^{ABC}	35.4	11.4^{ABC}	52	10.7^{ABCD}
3	29.7	16.5^{AB}	0	0^{C}	46.5	16.7^{A}	39.6	15.3^{A}	56.7	16.3^{A}
4	23.3	22.8^{AB}	0.1	0.3^{C}	36.3	13.3^{CD}	25.6	14.2^{D}	47.9	9.1^{D}
5	29.9	19.3^{AB}	0	0.2^{C}	44.6	14.7^{AB}	31.9	12.6^{ABCD}	54.9	13.3^{AB}
6	16.5	17.1^{ABC}	7.3	14.9^{BC}	43	12.9^{AB}	31.8	11.3^{ABCD}	50.8	11.9^{ABCD}
7	32.9	21.4^{A}	1.6	9.2^{C}	40.3	14^{ABCD}	28.6	13.5^{BCD}	49.3	8.7^{BCD}
8	11.2	17.7^{BC}	21.5	24.4^{AB}	42.7	13.8^{AB}	35.9	13.3^{AB}	51.5	11.2^{ABCD}
9	32.7	21.5^{A}	1.2	6.8^{C}	43.4	14.8^{AB}	31.8	13.4^{ABCD}	54.5	14.5^{ABC}
10	1.2	5.8^{C}	35.6	22.4^{A}	40.6	13.8^{ABCD}	34.4	12.9^{ABC}	51	10.2^{ABCD}
11	33.4	20.9^{A}	0	0^{C}	39	13.8^{BCD}	27.9	13.9^{CD}	50.5	12.4^{BCD}

Samples with the same letter (ABCD), within a column, are not significantly different from each other ($p < 0.05$).

an attribute can obtain by chance (1/number of attributes) (Pineau et al., 2009). The significance limit represents the smallest value of the proportion being significantly ($p = 0.05$) higher than the chance level. For example, for product 1, 'natural processed blackcurrant' was perceived as being the first dominant sensation (for 50% of the panel) at 8% of standardised time (Stdtime) and this is whilst panellists were still holding the product in their mouths. This dominance rate is higher than the significance level, so there is a significant consensus of the panel in perceiving 'natural processed blackcurrant' as the first dominant sensation at the beginning of the product evaluation. The sequence of dominant sensations for product 1 were then subsequently 'natural sweetness' (from 15% to 20% of Stdtime, with maximum dominance rate of about 58% at 18% of Stdtime), then 'natural processed blackcurrant' (at 25% Stdtime when the panellists were swallowing the products, with dominance rate of about 40%). After swallowing the product, the first perceived dominant sensation was 'acidic' (at 34% of Stdtime, with dominance rate of about 38%), followed by 'natural processed blackcurrant' (at 45% of Stdtime, with dominance rate of about 45%), 'natural sweetness' (from 50% to 70% of Stdtime, with maximum dominance rate of about 70% at 65% of Stdtime), 'natural processed blackcurrant' (from 70% to 85% of Stdtime, with maximum dominance rate of about 50% at 80% of Stdtime) and finally 'natural sweetness' (from 85% to 100% of Stdtime, with maximum dominance rate of about 60% at 92% of Stdtime). It is important to note that TDS dominance curves are not related to intensity but to the number of times an attribute has been cited as being a dominant sensation at a given time.

The TDS curves (Fig. 5) highlight differences in the sequence of dominant sensations. For example, product 1 was dominated by 'natural processed blackcurrant', then 'natural sweetness' and then 'acidic'. However, product 7 was dominated initially by 'natural sweetness' followed by 'natural processed blackcurrant'. Product 4 was continuously dominated 'tomato ketchup' with 'natural sweetness' also dominating towards the beginning and end of the assessment.

TDS dominance curves highlighted that 'fresh blackcurrant' and 'acidic' sensations were equally dominant for product 3 (Fig. 5) whereas 'tomato ketchup' sensation was dominant throughout the whole drinking process for product 4 (Fig. 5). On the other hand, products which contained more ingredients were equally dominated by sensations related to blackcurrant and sweetness. For example, 'natural processed blackcurrant' was found as dominant as 'natural sweetness' for added sugar squashes. i.e. products 1, 7, 8 and 11 except for product 5 which was mainly dominated by 'acidic' sensation in aftertaste (Fig. 5). On the other hand, artificially sweetened squashes, i.e. products 6 and 8 (Fig. 5) were equally dominated by 'natural processed blackcurrant' and 'artificial sweetness' whereas product 10 (Fig. 5) was equally dominated by 'confectionary blackcurrant' and 'artificial' sensations. Product 2 (Fig. 5), however, was mainly dominated by artificial sweetness, especially in the aftertaste.

4. Discussion

4.1. Sensory properties (QDA) of blackcurrant squash in relation to product composition

The flavour profile of blackcurrant squash was primarily influenced by the level of dilution, product composition, or the com-

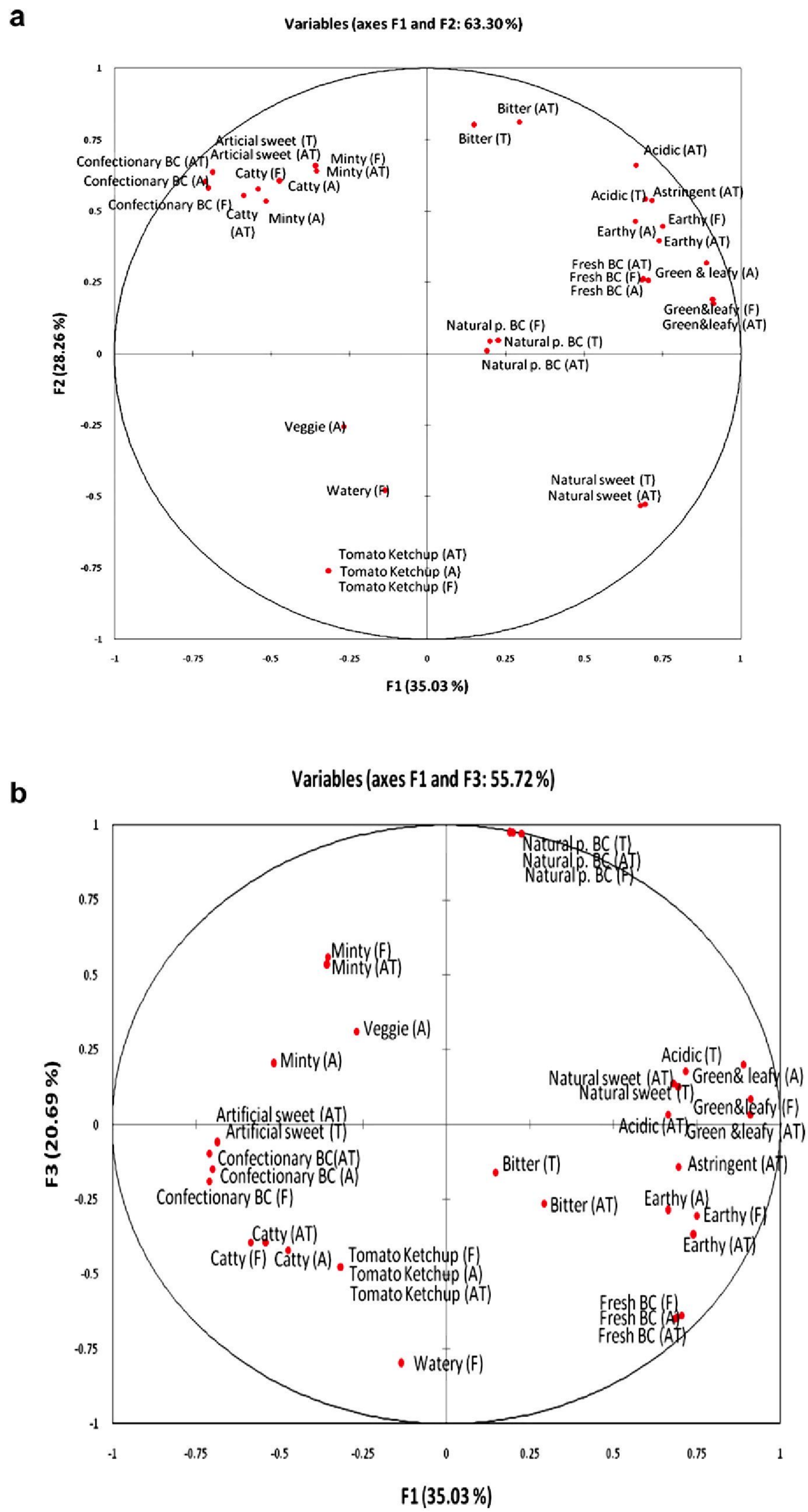

Fig. 1. PCA Correlation circles (a) PC1 versus PC2 and (b) PC1 versus PC3 from mean QDA panel data.

plexity of composition. Complex products, with a mid range of blackcurrant juice content made up using a dilution ratio of 1:5 (see Table 1) were characterised by 'natural processed blackcurrant'. However, when complex composition was combined with low blackcurrant juice (0.4% per 50 ml serving), the flavour profile was more 'confectionary blackcurrant'. Products with higher level

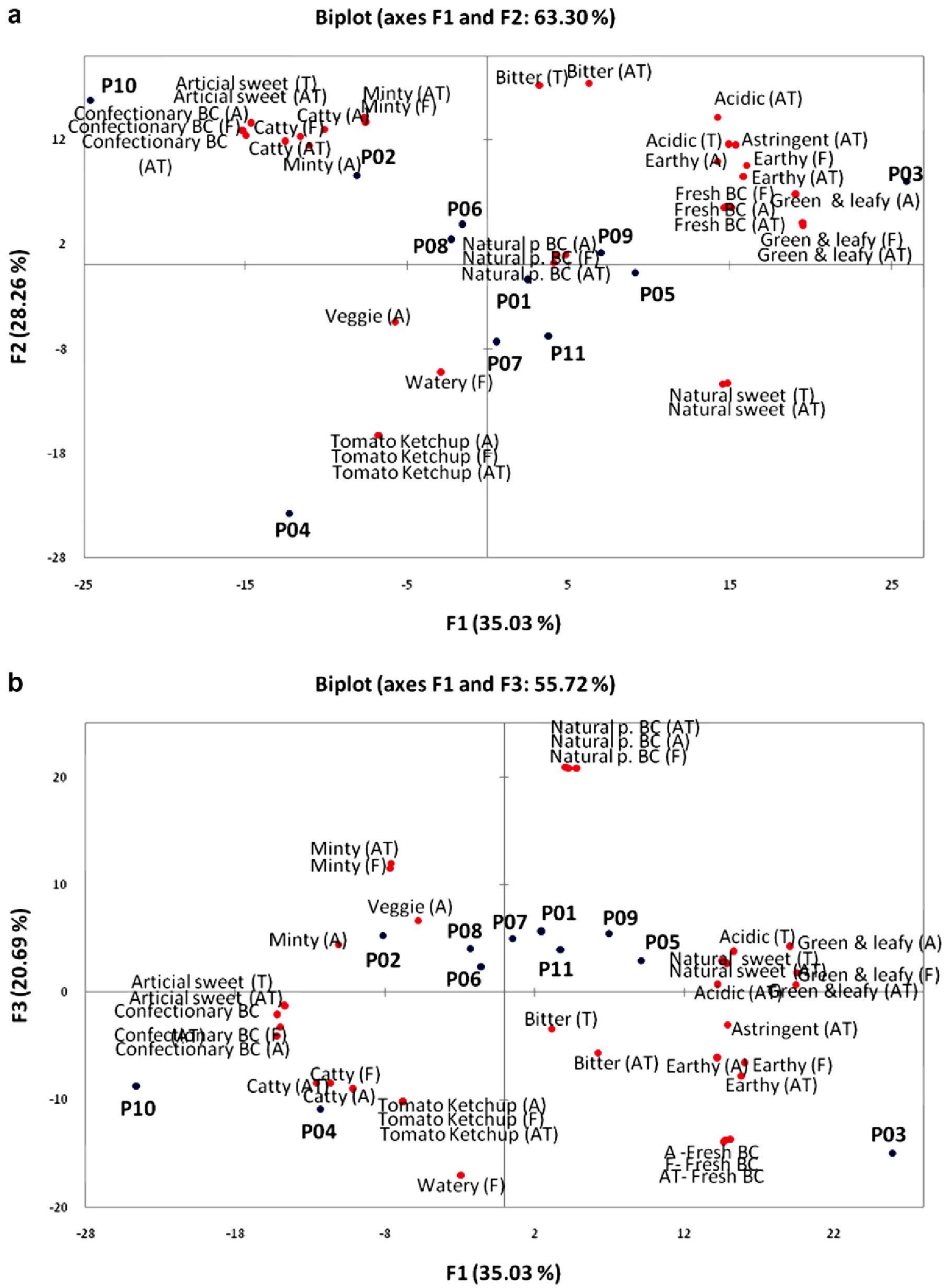

Fig. 2. Principal component analysis (PCA) biplots (a) PC1 versus PC2 and (b) PC1 versus PC3, from mean QDA panel data.

of blackcurrant juice were generally perceived as more 'bitter' and 'astringent' as well as 'acidic'. Phenolic compounds remain in berry skin-rich press residue and are thought to contribute to astringency and bitter taste (Sandell et al., 2009). When high blackcurrant juice was combined with a simple ingredient composition other flavours such as 'fresh blackcurrant', 'green and leafy' and 'earthy' became apparent.

Baldwin and Korschgen (1979) reported that aspartame sweetened products had a significantly higher fruit-flavour intensity than equally sweet products sweetened with sucrose. However,

Table 4
TDS SCORE (*stdev*) and post hoc test groupings for flavour intensity of 11 blackcurrant samples.

Product	Flavour										Taste							
	Blackcurrant		Catty		Tomato Ketchup		Earthy		Minty		Sweet		Acidic		Bitter		Astringent	
1	41.5	8.5^{AB}	0	0^{C}	0	0^{B}	0	0^{B}	6.7	13.7^{ABC}	46.5	9^{AB}	36.6	17.6^{ABCD}	13.9	15.3^{AB}	11.3	22.2^{BC}
2	31.8	11.7^{C}	0	0^{C}	0	0^{B}	2.2	7.3^{B}	11.9	16.7^{A}	47.7	12.8^{A}	26	17.5^{DEF}	17.0	15.6^{AB}	11.9	22^{BC}
3	44.6	13.4^{A}	0	0^{C}	0	0^{B}	13.5	16.3^{A}	0.4	1.8^{D}	21.9	20^{D}	47	14.9^{A}	23.0	18.3^{A}	16.9	24.8^{A}
4	3	6.8^{D}	0	0^{C}	43.6	10.5^{A}	0	0^{B}	0	0^{D}	37.8	18.6^{C}	18.9	19.8^{F}	12.2	13.7^{B}	9.6	19.2^{C}
5	34.2	8.7^{C}	4.2	12.7^{B}	0	0^{B}	0.7	3.2^{B}	3.3	9.3^{CD}	39.9	9.4^{BC}	40.5	17.8^{AB}	17.3	16.2^{AB}	11.5	22.7^{BC}
6	34.6	8.4^{C}	4.4	11.7^{B}	0	0^{B}	1.5	4.8^{B}	5.8	12.5^{ABCD}	40.2	11.3^{BC}	38.2	16.3^{ABC}	18.0	16.8^{AB}	14.8	24.1^{AB}
7	32.6	7.6^{C}	0	0^{C}	0	0^{B}	0	0^{B}	3.7	8.4^{CD}	45.2	11.1^{AB}	33.3	19^{BCDE}	15.8	15.0^{AB}	10.9	21.6^{C}
8	33.6	12.7^{C}	0	0^{C}	0	0^{B}	0	0^{B}	10.9	19.7^{AB}	49.6	13.3^{A}	26.8	18^{CDEF}	22.3	16.3^{A}	11.9	23.2^{BC}
9	36.5	6.6^{BC}	0	0^{C}	0	0^{B}	1.4	6.9^{B}	9.2	12.8^{ABC}	43.8	11.2^{ABC}	37.3	19^{ABCD}	16.0	15.0^{AB}	11.9	23.4^{BC}
10	30.4	13.2^{C}	23.7	17.9^{A}	0	0^{B}	0	0^{B}	5.5	10^{BCD}	44.8	11.3^{AB}	24	20.6^{EF}	20.3	18.1^{AB}	10.8	21.8^{C}
11	30.8	8.5^{C}	0	0^{C}	0	0^{B}	0	0^{B}	9.3	11.9^{ABC}	47.9	11^{A}	33.9	16^{BCDE}	12.2	$13.\ 9^{B}$	11.6	22.6^{BC}

Samples with the same letter (ABCD), within a column, are not significantly different from each other ($p < 0.05$).

this study shows no significant difference between artificially sweetened and added sugar products in terms of flavour suggesting a consistent enhancement of fruitiness by both sweeteners in a complex beverage. However, artificial sweeteners were found to modify the quality of sweetness and could also contribute to bitter notes. Even though some bitterness may come from artificial sweeteners (Wiet & Beyts, 1992), bitter components in the blackcurrant will also contribute to this attribute and may account for the observed overlap, suggesting that the type of sweetener modified the nature of the sweetness, and potentially blackcurrant, in the beverage. Although products containing a high juice to sugar ratio received high scores for acidity, there were no notable differences in acidity perception across the products and no correlation between pH and acidity score.

4.2. Developing the TDS attribute list

As TDS only enables a limited number of attributes to be assessed, it is crucial to select attributes that are salient for the product of interest. Meillon et al. (2009) selected attributes based on the number of citations made by the panel during discussion for TDS evaluation, but the present study has proposed an alternative way based on data obtained from previous QDA studies.

Selecting attributes for TDS using the initial QDA profile enabled meaningful product descriptions to be obtained from TDS data. Furthermore, QDA data enabled additional differentiation of some attributes on the TDS list, e.g. sweetness and blackcurrant flavour, without having to extend it to an unmanageable length. The number of attributes included for TDS could still be seen as a limitation, although only a small number of attributes can be mentally computed during the time available, probably no more than 10. In this study, some attributes had to be deleted and in this case it was those attributes that appeared least discriminating in the QDA, and which the panel did not originally feel were important temporally. Different blackcurrant and sweetness attributes were reduced to single attributes, thus loosing the added information on the nature of the attributes gained from QDA.

QDA enables attributes to be separated according to different stages e.g. attributes before consumption, during and after consumption. Although not used in this study, it is suggested that for TDS to accomplish this, adjustments could be made to the data collection process. It could be split into stages e.g. before consumption, in mouth and aftertaste, each with its own separate and relevant TDS list. In this study, TDS started with the product in mouth and so appearance and aroma attributes were ignored. Consequently, and not unexpectedly, the sensory characterisation of the products provided by TDS was not as detailed and comprehensive as QDA. For example, TDS did not include aroma and separate aftertaste characteristics and it was unable to record additional attributes, e.g. 'green and leafy', which discriminated between the products using QDA. A split stage approach could have included a pre consumption and/or aftertaste TDS assessment.

4.3. Comparing results (mean intensities) from QDA and TDS

The TDS score is a measure of attribute intensity that can be compared to that obtained for the same attribute from QDA studies. Interestingly TDS score was more discriminating for some attributes (Tables 3 and 4), for example, TDS pulled out products 5, 6 and 10 as being significantly more 'catty', whereas QDA only discriminated product 10 from the rest. However, QDA discriminated products 2 and 3 from the remainder regarding earthiness, whereas TDS only picked out product 3. It is possible that where an attribute has particular temporal dominance, TDS is more able to show differences in that attribute intensity but additional research would be required to test this further. This study shows that neither method is more discriminating, QDA simply allows for more attributes to be investigated.

The RV coefficient comparing the QDA and TDS data matrices for PCA indicated considerable agreement and, in both, the first 3 PCs accounted for around 84% of variation (Figs. 2 and 4). Clearly fewer attributes were available to the TDS PCA, and looking closely at the principal components some other differences were evident. For QDA, PC1 was correlated with 'fresh blackcurrant', 'earthy' and 'acidic' and opposing sweetness attributes (Fig. 2a). For TDS, PC1 still correlated with 'fresh blackcurrant', 'earthy' and 'acidic', but also with 'astringent' and 'bitter'. The sweetness attributes moved to PC2 (Fig. 4a). Although interpretation of the bi-plots yielded slightly different observations, each provided very similar findings in terms of product groupings. This suggests quite strongly that TDS measures of dominant attribute intensity reflect those provided by QDA, as was also concluded by Labbe et al. (2009).

4.4. Temporal information of blackcurrant squash (TDS) in relation to product composition

In time-intensity studies, aspartame sweetened beverages have been found to have longer sweetness and fruitiness durations than sucrose samples (Larsonpowers & Pangborn, 1978; Matysiak & Noble, 1991). This study showed no significant difference in durations of sweetness and fruitiness between the products sweetened by different artificial sweeteners or added sugar products. QDA data showed no correlation between sweetness and fruitiness (blackcurrant) ($r = 0.3$) and confirmed that the two attributes were independent. Temporal changes of dominance related to sweetness and fruitiness seemed to be affected by the complexity of ingredient

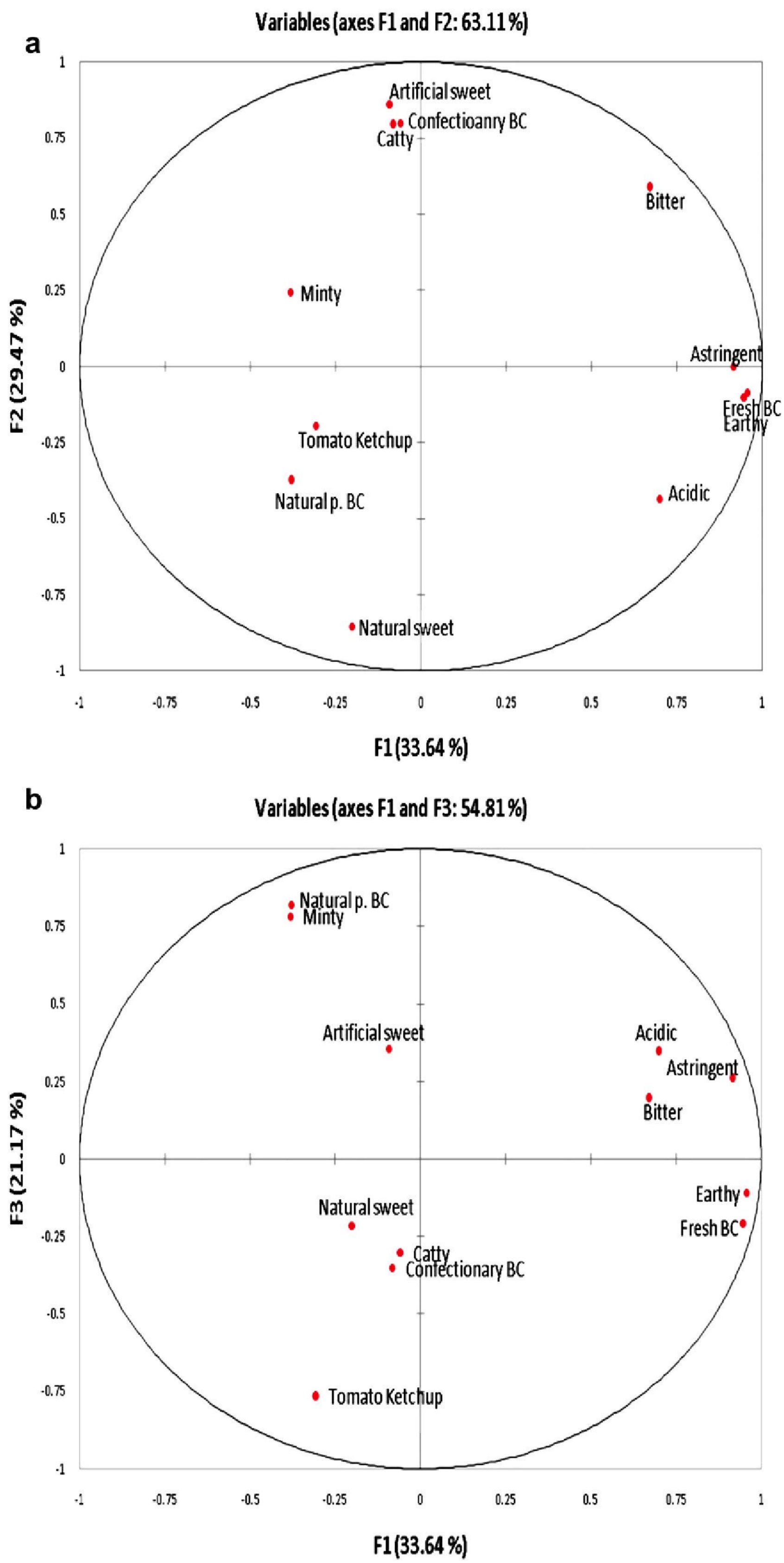

Fig. 3. Correlation circles (a) PC1 versus PC2 and (b) PC1 versus PC3 from TDS Score data.

composition combined with blackcurrant juice content rather than the type of sweetener. Samples with complex sample composition were dominated by sweetness and for longer whereas samples with less complex composition were dominated by fruit flavour, suggesting that fruit flavour became more dominant when ingredients such as flavourings, acid and preservatives were removed.

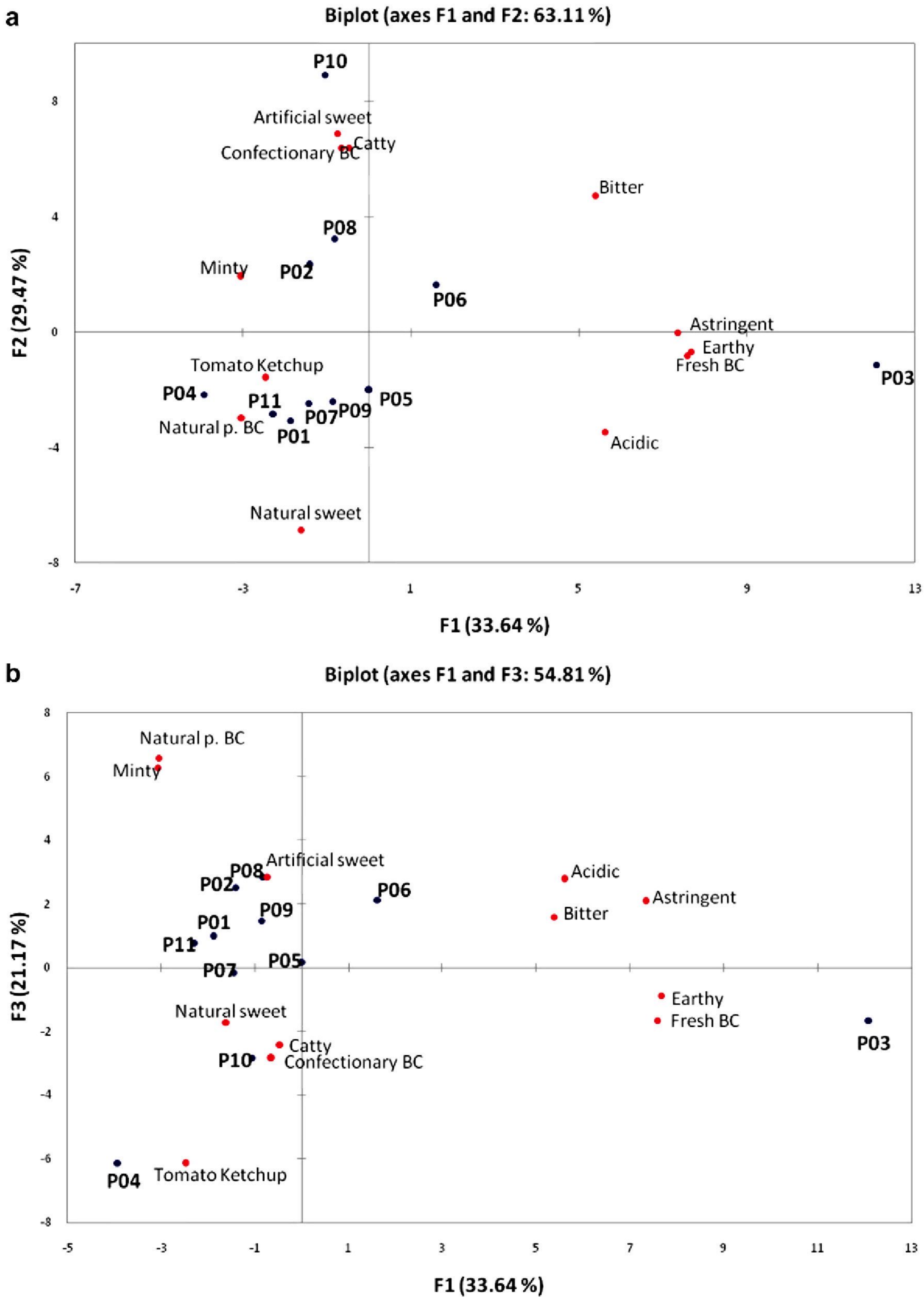

Fig. 4. Principal component analysis (PCA) biplots (a) PC1 versus PC2 and (b) PC1 versus PC3, from TDS score data.

Some scholars report no observed difference in the temporal perception of acidity between aspartame and sucrose sweetened products at any acid level (Bonnans & Noble, 1993). However, this study showed that temporal perception of acidity was more dominant and longer for added sugar squashes than artificially sweetened squashes at similar blackcurrant juice content. The ratio of

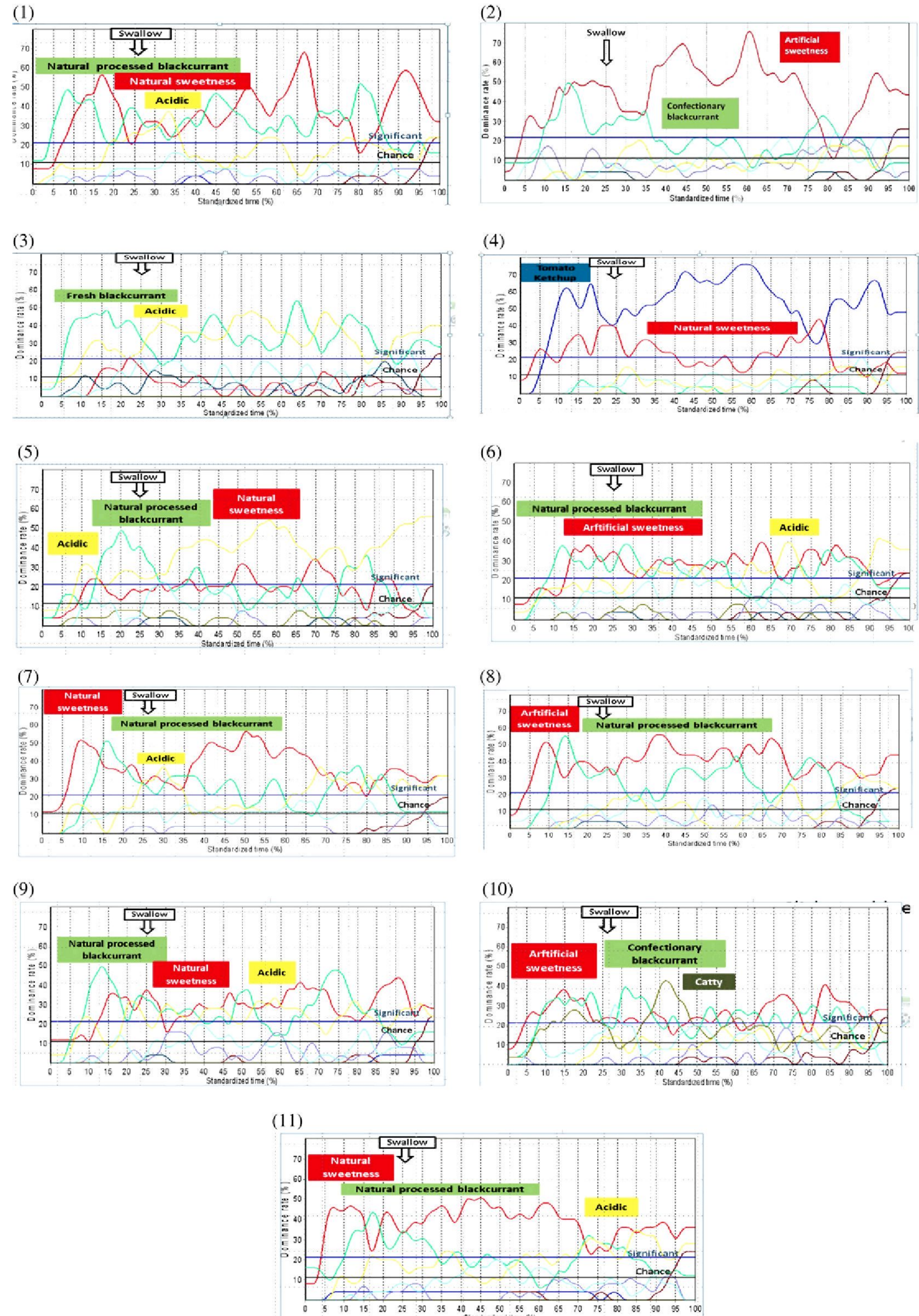

Fig. 5. Standardised TDS curves of dominance rate (i.e. proportion of subjects scoring each attribute) versus standardised time (%) for products 1–11.

blackcurrant juice content and sugar also seemed to affect the dominance of acidity in naturally sweetened products. Acidity was mainly found as a dominant sensation in products with high juice and low sugar content as illustrated by products 3 and 5 (Fig. 3). In addition, TDS dominance curves also showed that when acidity became dominant, sweetness became less dominant, provided evidence that sweetness and sourness were mutually suppressive in this product set, as has been shown in many other studies (Schifferstein & Frijters, 1990, 1991).

4.5. Relative merits of QDA and TDS

An obvious merit of TDS was the temporal information it provided differentiating products which shared similar sensory characteristic. For example, whilst QDA grouped products 1, 2, 5, 6, 7, 8, 9, 11 together, TDS was able to highlight that products 1, 6 and 9 started with a dominance of blackcurrant, then sweetness, whereas products 7, 8 and 11 started with a dominance of sweetness, then blackcurrant (data before swallowing). This study supports previous findings (Labbe et al., 2009a; Meillon et al., 2009) underlining the drawback of QDA in estimating the qualitative changes of dominant sensations during and after product consumption. For example, added sugar squashes, i.e. products 1, 7, 9 and 11 were scored higher in intensity for acidity than sweetness with QDA but such scales are not comparable in terms of intensity and as such it would not be possible to determine which attribute was dominant. TDS clearly identified that sweetness dominated not acidity.

TDS dominance curves identify when attributes became dominant and how long they were dominant for. For example, product 10 was characterised by its unique 'catty' note in QDA, but TDS showed catty only became dominant as aftertaste (Fig. 5). In addition, added sugar squashes, i.e. products 1, 7, 9 and 11 scored high in acidity intensity, but were found to be dominated by sweetness rather than acidity with TDS. This illustrates that the concept of dominance is independent of the concept of intensity.

One aspect of the originality of this work was basing attribute selection for TDS on QDA data. TDS cannot replace QDA completely since a QDA study has to be done prior to TDS. Unlike TDS, QDA allows more attributes to be investigated. For example, whilst TDS highlighted that product 3 was mainly dominated by 'fresh blackcurrant' and 'acidic', QDA was identified other complex flavours such as 'veggie' 'green and leafy' and 'earthy', which may contribute to product acceptability and differentiation and TDS did not capture this.

Panellists need to be highly motivated and focused for TDS measurement as it requires the panellist to concentrate constantly over the given timescale and select and rate attributes simultaneously. If the panel are not familiar with the product category, considerable time will still need investing in defining attributes and training the panel to rate them. However, once a panel is trained on the attributes through QDA, TDS methodology was quickly learned and adapted, was relatively quick to perform and provided data with added value.

Although QDA and TDS methodologies were shown to provide both qualitative and quantitative information, they are designed to satisfy different needs. QDA aims to describe and quantify the intensity of a larger number of attributes, whereas TDS illustrates the temporal sequence of dominant sensations. As QDA allows more attributes to be investigated, it remains important in the product development context. TDS should not be viewed as a potential equivalent or replacer to QDA, but a method dedicated to meet other objectives such as understanding temporal pattern of dominant attribute which then be used to relate to certain food experience or emotion (e.g. thirst quenching, refreshing or happy etc.). In fact, used together as complementary techniques they can provide a more rounded product profile.

5. Conclusion

Previous studies with TDS have focused on model systems, but this is the first study to use a sequential approach of QDA and TDS to measure and identify the sensory characteristics associated with the commercial UK blackcurrant squash product space. Data from QDA was used to determine the choice of attributes for TDS. Although TDS was limited in the number of attributes it could assess, it appeared to differentiate products in a similar manner to QDA. Both produced similar levels of discrimination and PCA analyses of intensity scores provided very similar bi-plots. Both methods indicated that the flavour profile was primarily influenced by the level of dilution, complexity of sample composition and blackcurrant juice content. Artificial sweeteners were found to modify sweetness quality and could also contribute to bitter notes. Interestingly, perception of acidity was not dependent on pH level but dependent on the ratio of blackcurrant juice and sugar content.

Using QDA and TDS in tandem was shown to be more beneficial than each just on its own. For example, mean intensities provided by QDA could not be used to predict the dominant sensations as well as their temporal changes. Nevertheless, TDS only enables the evaluation of a limited number of attributes and so cannot replace QDA completely as subtle, less dominant, attributes may also contribute to product differentiation. The study indicates that combining the two methods in a sequential approach can be used in a commercial context, and, more importantly, enables a fuller profile of the product category to be obtained.

References

Baldwin, R. E., & Korschgen, B. M. (1979). Intensification of fruit flavors by aspartame. *Journal of Food Science, 44*, 937.

Bonnans, S., & Noble, A. C. (1993). Effect of sweetener type and of sweetener and acid levels on temporal perception of sweetness, sourness and fruitiness. *Chemical Senses, 18*, 273–283.

Chaya, C., Perez-Hugalde, C., Judez, L., Wee, C. S., & Guinard, J.-X. (2004). Use of the STATIS method to analyze time-intensity profiling data. *Food Quality and Preference, 15*, 3–12.

Clark, C. C., & Lawless, H. T. (1994). Limiting response alternatives in time-intensity scaling: an examination of the halo-dumping effect. *Chemical Senses, 19*, 583–594.

Cliff, M., & Heymann, H. (1993). Development and use of time-intensity methodology for sensory evaluation – a review. *Food Research International, 26*, 375–385.

Cordella, C. B. Y., Leardi, R., & Rutledge, D. N. (2011). Three-way principal analysis applied to noodles sensory data analysis. *Chemometrics and Intelligent Laboratory System, 106*, 125–130.

Dijksterhuis, G. B., & Piggott, J. R. (2000). Dynamic methods of sensory analysis. *Trends in Food Science and Technology, 11*, 284–290.

Dijksterhuis, G. B., Flipsen, M., & Punter, P. H. (1994). Principal component analysis of time intensity data. *Food Quality and Preference, 5*, 121–127.

Duizer, L. M., Bloom, K., & Findlay, C. J. (1996). Dual-attribute time-intensity measurement of sweetness and peppermint perception of chewing-gum. *Journal of Food Science, 61*, 636–638.

Eilers, P., & Dijksterhuis, G. B. (2004). A parametric model for time intensity. *Food Quality and Preference, 15*, 239–245.

Jack, F. R., Piggott, J. R., & Paterson, A. (1994). Analysis of textural changes in hard cheese during mastication by progressive profiling. *Journal of Food Science, 59*, 539–543.

Labbe, D., Schlich, P., Pineau, N., Gilbert, F., & Martin, N. (2009). Temporal dominance of sensations and sensory profiling: a comparative study. *Food Quality and Preference, 20*, 216–221.

Larsonpowers, N., & Pangborn, R. M. (1978). Paired comparison and time-intensity measurements of sensory properties of beverages and gelatins containing sucrose or synthetic sweeteners. *Journal of Food Science, 43*, 41–46.

Le Reverend, F. M., Hidrio, C., Fernandes, A., & Aubry, V. (2008). Comparison between temporal dominance of sensations and time intensity results. *Food Quality and Preference, 19*, 174–178.

Ledauphin, S., Evelyne, V., & Qannari, E. M. (2006). A procedure for the analysis of time intensity curves. *Food Quality and Preference, 17*, 290–295.

Matysiak, N. L., & Noble, A. C. (1991). Comparison of temporal perception of fruitiness in model systems sweetened with aspartame, an aspartame + acesulfame K blend, or sucrose. *Journal of Food Science, 56*, 823–826.

Meillon, S., Urbano, C., & Schlich, P. (2009). Contribution of the temporal dominance of sensations (TDS) method to the sensory description of subtle differences in partially dealcoholized red wines. *Food Quality and Preference, 20*, 490–499.

Ovejero-López, I., Bro, R., & Bredie, W. L. P. (2005). Univariate and multivariate modelling of flavour release in chewing gum using time-intensity: a comparison of data analytical methods. *Food Quality and Preference, 16*, 327–343.

Piggott, J. R. (2000). Dynamism in flavour science and sensory methodology. *Food Research International, 33*, 191–197.

Pineau, N., Cordelle, S., & Schlich, P. (2004). Méthode d'acquisition, de codage et d'analyse de profiles sensoriels temporels. *8ème journées Agro-industrie et méthodes statistiques*. March 10–12, 87–94.

Pineau, N., Schlich, P., Cordelle, S., Mathonniere, C., Issanchou, S., Imbert, A., et al. (2009). Temporal dominance of sensations: construction of the TDS curves and comparison with time-intensity. *Food Quality and Preference, 20*, 450–455.

Pionnier, E., Nicklaus, S., Chabanet, C., Mioche, L., Taylor, A. J., Le Quere, J. L., et al. (2004). Flavour perception of a modal cheese: relationships with oral and physico-chemical parameters. *Food Quality and Preference, 15*, 843–852.

Sandell, M., Laaksonen, O., Jarvinen, R., Rostiala, N., Pohjanheimo, T., Tiitinen, K., et al. (2009). Orosensory profiles and chemical composition of black currant (*Ribes nigrum*) juice and fractions of press residue. *Journal of Agriculture and Food Chemistry, 57*, 3718–3728.

Schifferstein, H. N. J., & Frijters, J. E. R. (1990). Sensory integration in citric acid/sucrose mixtures. *Chemical Senses, 15*, 87–109.

Schifferstein, H. N. J., & Frijters, J. E. R. (1991). The effectiveness of different sweeteners in suppressing citric cid sourness. *Perception and Psychophysics, 49*, 1–9.

Stone, H., Sidel, J. L., Oliver, S., Woolsey, A., & Singleton, R. C. (1974). Sensory evaluation by quantitative descriptive analysis. *Food Technology, 28*, 24–33.

Wiet, S. P., & Beyts, P. K. (1992). Sensory characteristics of sucralose and other high intensity sweeteners. *Journal of Food Science, 57*, 1014–1992.

Zimoch, J., & Findlay, C. J. (2006). effective discrimination of meat tenderness using dual attribute time intensity. *Journal of Food Science, 63*, 940–944.